FLUID COMPOSITES AS ALTERNATIVES TO SOLID ELECTRICAL COMPONENTS

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ABSTRACT

Today, most electronics and robots are composed of solid metals and semiconductors and composites based on them. As alternative, we propose “Electrofluids”, that exhibit electrical conductivity while flowing. We create highly concentrated suspensions of conductive particles -carbon black (CB) and carbon nanotubes (CNTs)- in solvents with different polarity and viscosity. The idea is to create 3D networks of the solid fillers that allow for electron transport like in solid composites, but here, the contacts between the particles are transient. The particles can move in the liquid and rearrange under mechanical deformations.

We studied the electrical properties of different mixtures as a function of the filler content and found that the amount of it required to achieve electrical conductivity in the material (percolation threshold) strongly depends on a) the polarity of the solvent matrix, b) its viscosity, and c) the shape of the particles.

Using carbon black (CB) as conductive filler, we observed a decrease in the percolation threshold from 8.34 wt%, when dispersed in PDMS to 0.55 wt%, when glycerol was used. Both pure solvents have a comparable viscosity (on the order of 10^3 mPa·s), but whereas glycerol is a polar molecule, PDMS is composed of hydrophobic polymer chains. The percolation threshold can be further reduced to 0.26 wt%, by using ethylene glycol (a polar solvent with a lower viscosity, on the order of 10 mPa·s). When using CNTs as filler, the percolation threshold for the glycerol mixture is lowered to 0.05 wt%. This reduction can be attributed to the high aspect ratio (around 150) of the CNTs.

The electrical properties of these materials are dominated by the 3D network formed by the filler. To understand the network’s structure and its dynamics, we performed rheological and rheoelectrical studies. All the samples at concentrations above percolation presented a shear thinning behaviour. Amplitude sweeps experiments revealed a clear correlation between the changes in the electrical properties and the shape of the storage and loss moduli, G’ and G’’.

We exploited this behaviour and created soft strain sensors. The Electrofluids were then encapsulated in elastomeric tubes and underwent uniaxial deformations. We performed cyclic and stress relaxation tests and found large differences in the mechanoelectrical performance (sensitivity and time dependency) of the mixtures. We will discuss their applicability in truly soft electrical devices.